Continue Measurement and Analysis of Geologically Induced Clutter in Seafloor Scattering

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LONG-TERM GOALS

The long-term goals of this effort are to:

- Characterize acoustic clutter in a manner that will lead to its mitigation.
- Improve the understanding of the effects of seafloor morphology and composition on scattering and clutter.
- Improve geo-acoustic parameter extraction from reverberation data.
- Improve our understanding of the multi-static physical mechanisms (below 5kHz) which scatter incident energy into a receiver and which can possess target-like characteristics (clutter).
- Construct suitable current high fidelity reverberation and scattering models for model/data comparison and inversion.

OBJECTIVES

The objectives of this effort are to:

- Design experiments (including modeling support) to discriminate interface scattering from volume inhomogeneities in the ocean bottom in support of geologic clutter reduction studies.
- Use the K-distribution-based techniques of Abraham to statistically characterize the clutter seen on STRATAFORM.
- Continue the validation and improvement efforts on the automated geo-acoustic parameter extraction technique developed by the PI.
- Use the new cardioid data from FORA to assess the utility of this technology for reverberation analysis.
- Operate, maintain and improve FORA hardware and data acquisition systems and participate in ocean experiments in support of acoustic clutter reduction program.

APPROACH

Two experiments have been designed and conducted in support of the clutter reduction effort at ONR. These were large experimental efforts, conducted after extensive planning, near the New Jersey STRATAFORM area in the springs of 2001 and 2003. These experiments involved researchers from MIT, SACLANTCEN, ARL-PSU, NUWC and NRL [1]. ONR's Mace Program Office contributed

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bistatic source assets to the first experiment. The PI participated in additional experimental efforts that were conducted under the Boundary Characterization Joint Research Program with SACLANTCEN, ARL-PSU, NRL, and DREA of Canada. Those experiments focused more generally on the characterization of ocean boundary interactions but have several objectives in common with the Acoustic Clutter program. Boundary Characterization experiments were conducted in the springs of 2000, 2001 and 2002. Some of this data could be very helpful to the clutter reduction studies since the STRATAFORM was the primary site of the 2001 Boundary experiment. Another Boundary test is scheduled for the spring of 2004 in the Malta Plateau area.

For the Acoustic clutter experiments data were taken over a wide a set of bistatic and monostatic geometries, ranges, frequencies, and pulse parameters to permit broad band analysis and also to test inversion schemes for important geo-acoustic and scattering parameters. Assessing the scattering characteristics of buried features like the meandering river channels identified by Goff, Austin and other ONR researchers has been one of the main priorities (see [2] for example).

For the analysis phase, the issue of separating seafloor interface scattering from sub-bottom feature and volume scattering in the bottom is being studied. Recent work noted the importance of fine scale roughness characterization for the Bragg-like scattering component [3]. A study of surface morphology using the high resolution STRATAFORM bathymetry data will be made and compared with fractal (e.g., Goff Jordan) and composite roughness models (e.g. Jackson [4]) to assess merits of these approaches. Refinements to surface roughness models may be implemented where needed.

The manual inverse scheme used by Preston and Ellis for Rapid Environmental Assessment (REA) [5-7] involved a forward model and match approach using the Generic Sonar Model (GSM) [8] and *apriori* information when possible. That scheme was automated to speed up the bottom parameter estimation process with a simulated annealing (SA) algorithm [11]. This permits near real-time higher quality performance predictions to be made. Minimum least squared error norms have been developed and used to evaluate the results. Using the work of Hamilton [10] and guidance from C. Holland, the PI has developed a constrained SA algorithm, which narrows the solution search space. The procedure currently uses the reverberation computations of GSM and the bottom loss estimates of ORCA but new reverberation models are being developed (see below). Recently a multi-frequency optimization capability has been added to the algorithm. The SA inversion methodology has been used on 2000 and 2001 broadband REA reverberation data taken by ARL/Penn State and SACLANTCEN [11,12] as well as some HEP data. The newer scattering strength models developed by Jackson et. al., have also been incorporated into the automated inversion scheme. With the high quality of geo-acoustic ground truth available from the STRATAFORM area, these data sets should be ideal for testing such inverse schemes.

The PI has begun an effort to statistically characterize the clutter seen on STRATAFORM using methods developed by Abraham [13]. Initial results [14], showed many data segments of matched filtered amplitudes examined to be significantly non-Rayleigh. This is likely due to the spikiness seen in much of the 2001 Acoustic Clutter Experiment data in the polar displays. This work is being extended to complete a thorough parameterization of the area. An article has been submitted to the J. of Oceanic Engineering on progress to date. Abraham has recently used a K-distribution-based model to estimate an effective number of scatterers on a beam. This methodology is being applied to the STRATAFORM data will be correlated with local measurements of geoacoustic properties being made by Austin, Goff and Holland in hopes of correlating some of the unexplained clutter with bottom properties/ other conditions that could most likely cause problems but that may not be buried features.

A range dependent reverberation model will be constructed to improve the automated geo-acoustic parameter extraction technique developed by the proposed PI. The Existing 2-D pressure field models ORCA by Westood at ART/UT [15] and Evan's COUPLE [16] will be used as the propagation engines. Real 3–D effects for data taken on horizontal line arrays using directional sources have been incorporated into normal mode based models like OGOPOGO by Ellis [17]. These techniques will be adapted for the 2-D research codes and modifications made in a way to minimize run times. Using the SACLANTCEN reverberation data resident at ARL Penn State and 2001 and 2003 Acoustic Clutter data, the new model will be compared with diffuse reverberation data selected above to assess the models suitability/applicability to these data sets. Improvements in the Jackson-Mourad scattering kernel being used in this technique may be sought to make it more suitable for multi-layer bottom environments. Validation efforts with the proposed PI's geo-acoustic parameter extraction technique would continue with a new range dependent forward model being a significant improvement.

Lastly, the cardioid capability of the FORA will be studied for its use as a discriminant against both diffuse reverberation and clutter. Optimum beamforming algorithms will be investigated.

WORK COMPLETED

The PI helped plan and then participated in ONR's 2001 and 2003 Acoustic Clutter Experiments (run by MIT's N. Makris) for reverberation in the STRATAFORM off New Jersey in the springs of 2001 and 2003. Major updates to old pulse processing software were developed to run in near real time for beamformed and matched filtered output. Geoclutter reverberation data from 2001 were analyzed at sea and initial results reported at the Geoclutter/Boundary Characterization workshop of Oct 2001 in Halifax [13]. That processing was adapted for the new FORA (with considerable help this time from MIT) to process the 2003 data.

Significant improvements were also made to the REA bottom parameter estimation methodology using the simulated annealing technique described above. The PI also helped plan and then participated in the Boundary Characterization 2000, 2001 and 2002 experiments (run by SACLANTCEN's C. Holland and P. Nielsen), designed to measure bottom loss, local scattering, diffuse reverberation, pulse spreading and water-column volume scattering in the STRATAFORM. Using the new REA techniques, reverberation data were analyzed at sea and initial results from 2001 were reported at the Geoclutter/Boundary Characterization workshop of Oct 2001 in Halifax [12]. The results from 2000 are reported in a SACLANTCEN report (SR-414). Techniques have been significantly improved for both data processing and post experiment analysis.

The PI has also spent considerable effort in overseeing the building and final tweaking of the new ONR Five Octave Research Array (FORA) at Penn State, under a DURIP award. This new array was just used in the very successful 2003 Acoustic Clutter follow-on experiment. The FORA also recently completed a very successful sea trial, T-Mast 02, (July 2002), where a significant amount of data was collected using it as one of the primary receivers.

RESULTS

Recent results from reverberation analysis on the 2001 experiments and the 2000 Boundary Characterization experiment were reported in [11-13]. As an example, Figure 1 below shows a polar display of bistatic reverberation from the STRATAFORM, on the new FORA towed array in a 50 Hz band centered at 415 Hz. Reverberation is color-coded vs. intensity and time is mapped bistatically into location. Fig. 1 also contains the STRATAFORM bathymetry, (in black), sub-bottom horizons (in red) and small surficial features like iceberg scours. Buried river channels, the dendritic structures in black, are also shown (overlay provided by Goff [2]). The arrow indicates the towed array heading. The source was an LFM pulse, 1 s in duration.

RELATED PROJECTS

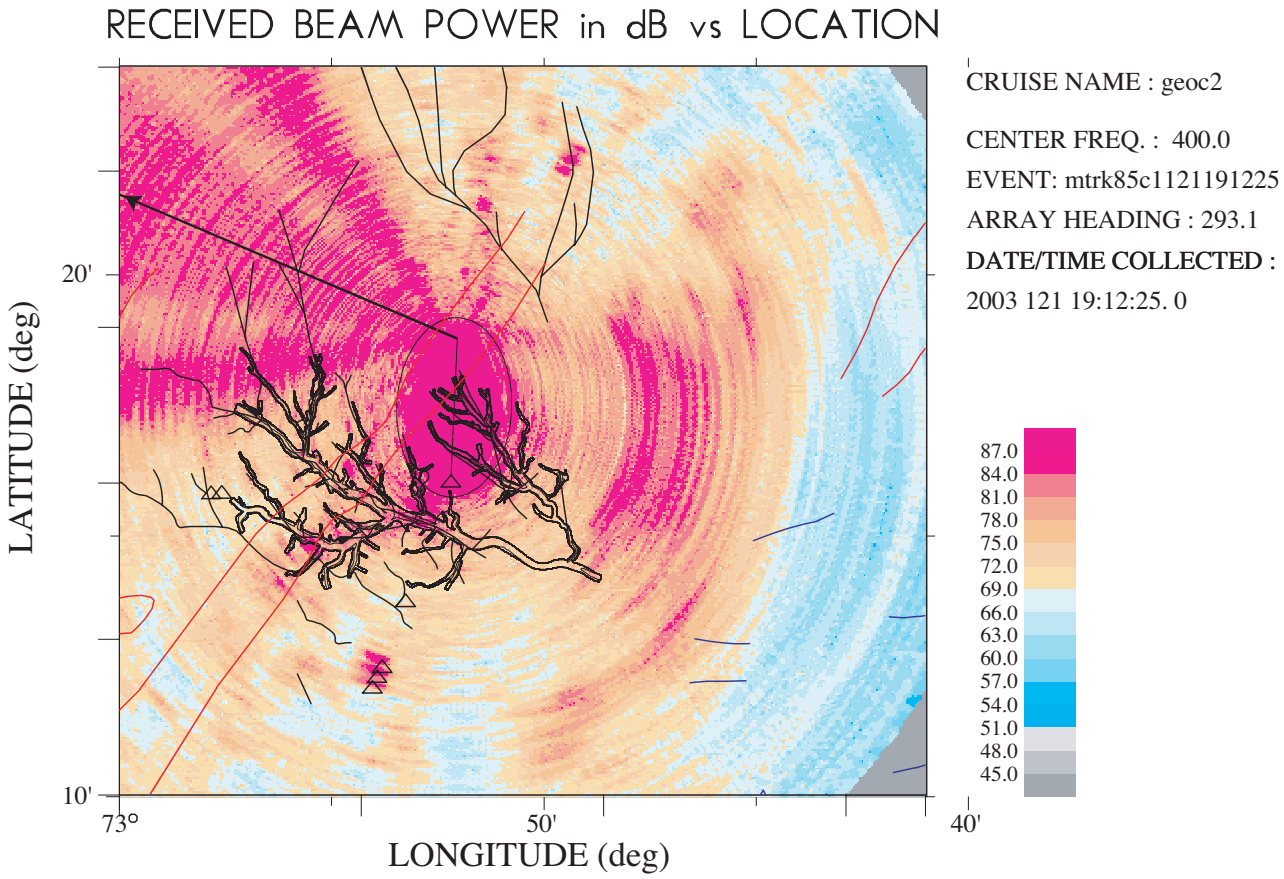

Fig. 1. Polar plot of the bistatic matched filtered reverberation on STRATAFORM from a pulse in a 50 Hz band centerered at 415 Hz. The black arrow direction indicates the array heading, the base of the arrow the array position and the triangle due south of the array is the source position.

IMPACT/APPLICATIONS

A better understanding of sonar clutter is key to improving sonar usability in shallow water. The new FORA will be a an exciting new tool for ONR's Ocean Acoustic researchers. A wide area-averaged bottom parameter estimation technique using simulated annealing for Rapid Environmental

Assessment such as described here and that utilizes directional reverberation measurements could provide a quick way to estimate sonar performance and optimize asset deployment.

TRANSITIONS

These same REA techniques have recently been applied to select data from recent HEP experiments as part of ONR 6.2 efforts lead by Dr. R. Wayland in support of the TAMBDA program at NAWC. In addition, a new effort is planned to incorporate the above inversion concepts and reverberation models into a multi-static parallel toolbox – an effort that will also be led by Dr. Wayland.

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Plus parts of many Geoclutter and Boundary Characterization planning documents and towed array design and test inputs.